DOE/ID-11241

U.S. Department of Energy
Idaho Operations Office

Remedial Investigation and Baseline Risk Assessment for Operable Unit 7 13/14

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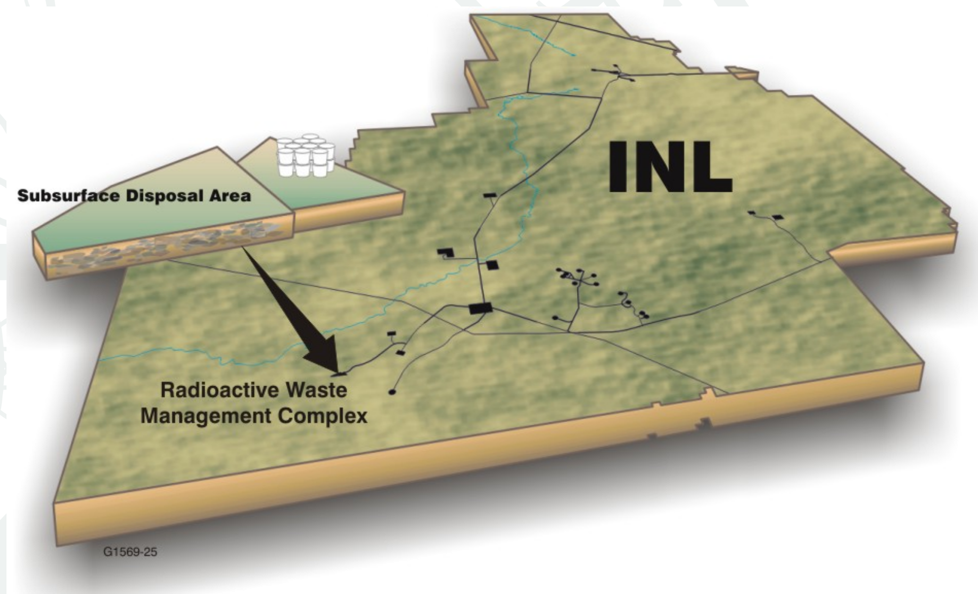

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Prepared for the
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ABSTRACT

The Subsurface Disposal Area is a radioactive waste landfill located within the Radioactive Waste Management Complex at the Idaho National Laboratory Site in southeastern Idaho. Contaminants in the landfill include hazardous chemicals, contact- and remote-handled fission and activation products, and transuranic radionuclides. This remedial investigation and baseline risk assessment characterizes the landfill and evaluates risk to human health and the environment posed by contaminants in the buried waste in the absence of any remedial action. Because this analysis shows unacceptable risk from the buried waste, the next step in the Comprehensive Environmental Response, Compensation, and Liability Act process is to perform a feasibility study to identify and evaluate remedial alternatives. The proposed plan, which will follow the feasibility study, will present a specific preferred remedial alternative to stakeholders. Alternatives being considered comprise the no action alternative, constructing an engineered surface barrier over the facility, in situ grouting, and exhuming part or all of the buried waste. The selected remedy will satisfy remediation goals to be established for this cleanup effort in a record of decision. This decision process is implemented through the Federal Facility Agreement and Consent Order between the U. S. Department of Energy, the Idaho Department of Environmental Quality, and the U. S. Environmental Protection Agency.

This report concludes that the Subsurface Disposal Area poses unacceptable risk to human health and the environment and recommends developing remedial alternatives to address those risks in a feasibility study. Twelve radionuclides and six nonradionuclides are identified as primary contaminants of concern for human health based on a 1,000-year simulation period: Am-241, C-14, Cs-137, I-129, Pb-210, Pu-239, Pu-240, Ra-226, Ra-228, Sr-90, Tc-99, Th-228, carbon tetrachloride, 1,4-dioxane, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene. Surface soil exposure pathways (i.e., external exposure, ingestion, and inhalation) pose the highest risks, particularly from Cs-137 and Sr-90, actinides (i.e., Am-241, Pu-239, and Pu-240), and actinide decay products (i.e., Pb-210, Ra-226, Ra-228, and Th-228). Groundwater ingestion risk drivers are C-14, I-129, Tc-99, carbon tetrachloride, methylene chloride, nitrate, tetrachloroethylene, and trichloroethylene.

EXECUTIVE SUMMARY

This comprehensive remedial investigation and baseline risk assessment (RI/BRA) for Waste Area Group 7 presents estimated cumulative human health and ecological risks associated with the Subsurface Disposal Area (SDA). The SDA is a radioactive waste landfill within the Radioactive Waste Management Complex (RWMC) at the Idaho National Laboratory (INL) Site. Waste Area Group 7 is synonymous with RWMC. Other facilities at RWMC include the Transuranic Storage Area (TSA) and adjacent administration and operations areas. The analysis in this report focuses solely on the SDA. Risk potential associated with the TSA and support facilities will be evaluated in the future after all stored waste is dispositioned and the TSA is closed.

The comprehensive remedial investigation and feasibility study (RI/FS) for Waste Area Group 7 is identified as Operable Unit 7-13/14 in the Federal Facility Agreement and Consent Order (FFA/CO) (DOE-ID 1991). The FFA/CO is a binding agreement between the U.S. Department of Energy (DOE), the Idaho Department of Environmental Quality (DEQ), and the U.S. Environmental Protection Agency (EPA). The FFA/CO provides the framework for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC § 9601 et seq., 1980) response actions at the INL Site. Typically, an RI/BRA is founded on site characterization data. Such data include monitoring results that are collected using sampling plans designed to support remedial decisions. Unlike a classical analysis, this RI/BRA depends on predicted concentrations developed through modeling rather than on currently detected concentrations. The DOE, DEQ, and EPA identified this approach as appropriate for the SDA because of the long half-lives of some radionuclides in the SDA and because of issues associated with representative sampling (e.g., sampling heterogeneous media such as fractured basalt and landfill waste). Section E-1.1 provides an overview of the RI/BRA, including summaries of site characterization data, modeling results, and risk estimates. Section E-1.2 presents conclusions and recommendations relating to development of the Operable Unit 7-13/14 feasibility study.

E-1.1 Overview

This RI/BRA presents site characterization data, modeling results, and estimates of cumulative human health risk and ecological risk associated with waste buried in the SDA. Evaluating risk is typically an iterative process; each iteration provides an increasingly refined assessment. This RI/BRA is the culmination of a series of risk assessments for Operable Unit 7-13/14, including the Interim Risk Assessment (IRA) (Becker et al. 1998) and the Ancillary Basis for Risk Analysis (ABRA) (Holdren et al. 2002). Improved versions of the same numerical models used in the IRA and ABRA were implemented to predict contaminant concentrations over time in environmental media. These predicted concentrations then were used to estimate risk.

The first four sections of this report present site characterization, comprising remedial investigation elements of this analysis. Sections 5 and 6 develop the baseline risk assessment. Information taken from the IRA and ABRA was updated to reflect additional information developed over the past few years. The regulatory setting for this RI/BRA and the physical setting for the INL Site and the SDA are described in Sections 1 and 2, respectively. Section 3 presents past and current RWMC operations (e.g., waste-generating process knowledge and other historical background information), summaries of various studies and activities, and other information used to assess the site. Section 4 provides a detailed analysis of the nature and extent of contaminants of potential concern in the buried waste and environmental media. Section 5 describes modeling to simulate future concentrations of contaminants of potential concern in environmental media, and Section 6 applies those concentrations to estimate potential human health and ecological risk associated with the SDA. The following subsections summarize each section of this RI/BRA.

E-1.1.1 Summary of Section 1—Introduction

Section 1 introduces the purpose, scope, schedule, and regulatory background for the Operable Unit 7-13/14 RI/BRA. The purpose of the RI/BRA is to provide DOE, DEQ, and EPA with a basis for future risk management decisions for Waste Area Group 7 under CERCLA (42 USC § 9601 et seq., 1980) and the FFA/CO (DOE-ID 1991). To fulfill that purpose, primary scope elements assess the nature and extent of contamination associated with Waste Area Group 7 and evaluate current and future cumulative and comprehensive risks to identify contaminants of concern. Schedule modifications over time are described, culminating with the current enforceable schedule, which calls for delivering the draft RI/BRA and draft feasibility study in August and December 2006, respectively. The draft RI/BRA was delivered in December 2005, 8 months ahead of the enforceable schedule.

Federal statutes, agreements, and enforceable deadlines govern CERCLA assessments of the INL Site and are the legal basis for remedial decisions. The INL Site was added to the EPA National Priorities List of Superfund sites (54 FR 48184, 1989) under CERCLA. The FFA/CO established the procedural framework for identifying appropriate actions that must be implemented to protect human health and the environment in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300), CERCLA, the Resource Conservation and Recovery Act (42 USC § 6901 et seq., 1976), and the Idaho Hazardous Waste Management Act (Idaho Code § 39-4401 et seq., 1983).

The Action Plan attached to the FFA/CO (DOE ID 1991) includes the original schedule for developing, prioritizing, implementing, and monitoring response actions. The FFA/CO Action Plan provides for remediating RWMC under the designation of Waste Area Group 7. For management purposes, the FFA/CO divided the INL Site into 10 waste area groups. Waste Area Group 7, comprising RWMC, is located in the southwestern quadrant of the INL Site (see Figure E-1). The FFA/CO Action Plan further divided Waste Area Group 7 into numerous operable units. Overall remediation of the SDA within RWMC is currently being evaluated through a comprehensive CERCLA RI/FS under combined Operable Unit 7-13/14. Ultimately, the RI/FS will lead to risk management decisions and selection of a final comprehensive remedial approach through development of a CERCLA record of decision. Recently, DOE, DEQ, and EPA determined that Waste Area Group 7 should exclude the TSA; therefore, the RI/BRA focuses only on waste buried in the SDA.

E-1.1.2 Summary of Section 2—Site Background

Section 2 describes important characteristics of the INL Site and RWMC. In addition to location and description, Section 2 summarizes the historical background, provides details of the physical setting (e.g., meteorology, geology, and hydrology), and addresses other important elements (e.g., flora and fauna, demography, land use, and cultural resources).

E-1.1.2.1 Historical Background. The INL Site, originally established in 1949, is a DOE-managed reservation that historically has been devoted to energy research and related activities. In mid-2003, the laboratory was restructured into two separate business units: one for laboratory research and development missions (i.e., INL) and one for cleanup activities (i.e., Idaho Cleanup Project [ICP]). In February 2005, two separate contractors assumed management of the two business units. This separation allows each organization to focus on its distinct mission: (1) the INL primary mission as the lead laboratory for U.S. nuclear energy research and (2) the ICP mission to remediate the environment and clean up historical contamination at the INL Site as quickly and efficiently as possible (Litus and Shea 2005).

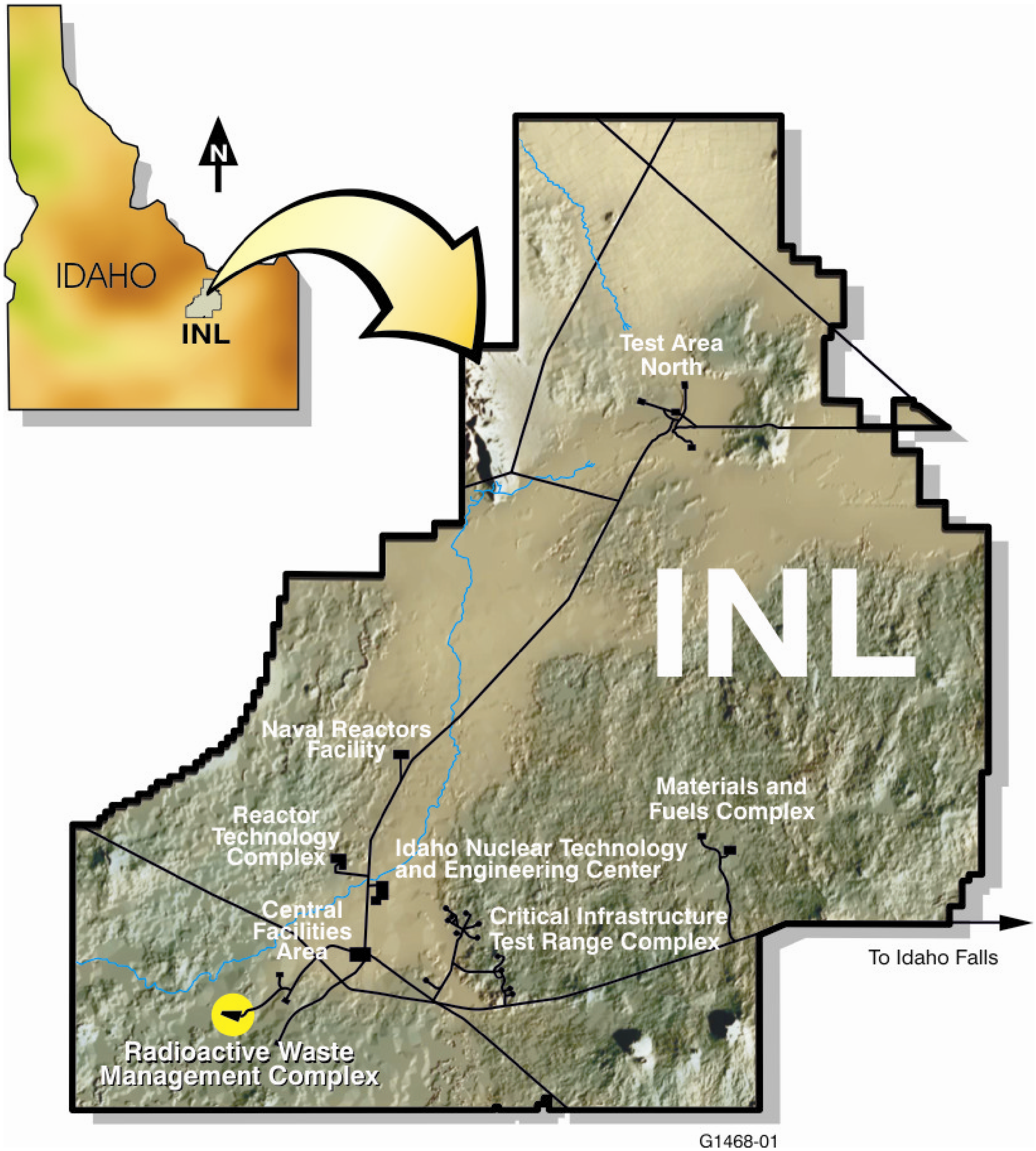

Figure E-1. Idaho National Laboratory Site.

Four federal government contractors operate facilities at the INL Site. Bechtel Bettis operates the Naval Reactors Facility; Bechtel BWXT Idaho, LLC, manages the Advanced Mixed Waste Treatment Project; CH2M-WG, Idaho, LLC, manages ICP; and Battelle Energy Alliance manages national laboratory functions and operates INL Site services. These contractors conduct various programs at the INL Site under the supervision of two DOE offices: the U.S. Department of Energy Idaho Operations Office and the DOE-Pittsburgh Naval Reactors Office. The U.S. Department of Energy Idaho Operations Office authorizes all government contractors to operate at the INL Site.

E-1.1.2.2 Physical Setting. The INL Site is located in southeastern Idaho (see Figure E-1) and occupies 2,305 km^2 (890 mi^2) in the northeastern region of the Snake River Plain. Regionally, the INL Site is nearest to the cities of Idaho Falls and Pocatello and to U.S. Interstate Highways I-15 and I-86. The INL Site extends nearly 63 km (39 mi) from north to south, is about 58 km (36 mi) wide at its broadest southern portion, and occupies parts of five southeastern Idaho counties.

The RWMC covers 72 ha (177 acres) (see Figure E-2), including the operations and administration area (approximately 9 ha [22 acres]), the SDA (39 ha [97 acres]), and the TSA (23 ha [58 acres]). Burial of radioactive waste in the SDA has resulted from building and operating a wide variety of reactor types at the INL Site and accepting for disposal radioactive and hazardous waste from outside facilities (primarily from the Rocky Flats Plant). Current environmental remediation activities at the INL Site include the following:

- Treating, storing, and disposing of waste
- Removing or deactivating facilities that are no longer of value
- Cleaning up historical contamination that presents risk to human health or the environment
- Preserving cultural resources
- Providing long-term stewardship (Litus and Shea 2005).

Local elevations across RWMC range from a low of 1,517.3 m (4,978 ft) to a high of 1,544.7 m (5,068 ft). Typically, soil in this southern portion of the INL Site is shallow and consists of fine-grained eolian soil deposits with some fluvial gravels and gravelly sand. Occasional pockets of thicker sediment layers form in depressions. Soil in the RWMC area was formed from several types of soil-genesis cycles, including deposition of loess, leaching of calcium carbonate, accumulation of clay, and erosion. The RWMC lies within a natural topographic depression that is associated with the fluvial systems of the Big Lost River and the Big Southern Butte. Some RWMC soil may be derived from historic stream deposits from the Big Lost River; however, evidence of erosion by these systems during the last 10,000 years is not evident.

Undisturbed surficial deposits within the RWMC area range in thickness from 0.6 to 7.0 m (2 to 23 ft) (Anderson, Liszewski, and Ackerman 1996). Irregularities in soil thickness generally reflect the undulating surface of underlying basalt flows. Many physical features are common within the soil stratigraphy of the RWMC area (e.g., pebble layers, freeze-thaw textures, glacial loess deposits, and platy caliche horizons). Surface soil at RWMC has been significantly disturbed and recontoured, and additional backfill—in several cases, sediment from the spreading areas—has been added for subsidence and runoff control. Enclosed by a constructed containment dike, RWMC has been recontoured on many occasions because of disposal and retrieval operations, remedial actions, subsidence mitigation, and surface-drainage modifications.

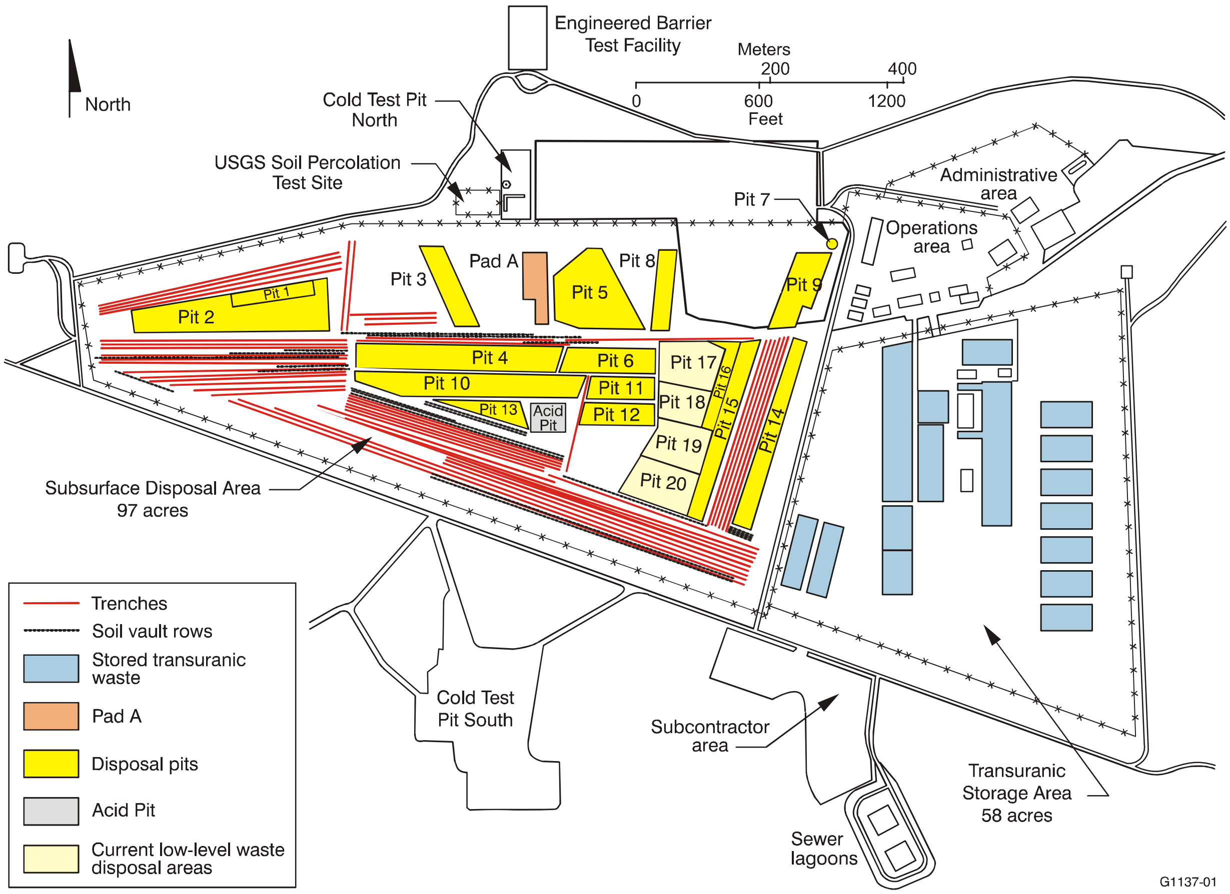

Figure E-2. Radioactive Waste Management Complex.

The INL Site region is classified as arid to semiarid because of low average rainfall of 22.1 cm/year (8.7 in./year). The RWMC has no permanent surface water features; however, the local depression tends to hold precipitation and to collect additional runoff from surrounding slopes. Surface water from episodes of rain or snowmelt eventually either evaporates or infiltrates into the vadose zone (i.e., unsaturated subsurface) and the underlying aquifer (Holdren et al. 2002). Below the shallow surficial sediment is a thick sequence of basalt flows intercalated with thin sedimentary interbeds. The regional subsurface consists mostly of these layered basalt flows with a few comparatively thin layers of sedimentary interbeds. Interbeds tend to retard downward water migration to the aquifer and are important features in assessing the fate and transport of contaminants. Because subsurface formations are unsaturated most of the year, they are characterized as a vadose zone; however, ephemeral lenses of perched water have been detected in association with interbeds.

The Snake River Plain Aquifer underlies RWMC at an approximate depth of 177 m (580 ft) and flows generally from northeast to southwest. The aquifer is bounded on the north and south by the edge of the Snake River Plain, on the west by surface discharge into the Snake River near Twin Falls, Idaho, and on the northeast by the Yellowstone basin. The aquifer consists of a series of water-saturated basalt layers and sediment. Local perturbations and seemingly anomalous behavior are observed for water levels in the RWMC area. Pump-test results from RWMC area wells show that a region of low permeability is present south and southwest of the RWMC area (Wylie and Hubbell 1994; Wylie 1996).

E-1.1.2.3 Demography, Flora and Fauna, and Cultural Resources. Populations potentially affected by INL Site or RWMC activities primarily are composed of workers, ranchers, people in neighboring communities, and members of the Shoshone-Bannock Tribes. Approximately 8,000 people currently work at INL Site facilities, though only a fraction of this population visits RWMC (Litus and Shea 2005). Ranchers graze livestock in areas on or near the INL Site; approximately 60% of the INL Site is used for grazing. Residential populations live in neighboring communities comprising the five Idaho counties bordering the INL Site; populations are sparse, ranging from 15 to 62 residents per square mile. No permanent residents live within the boundaries of the INL Site. Members of the Shoshone Bannock Tribes are allowed access to areas of cultural and religious significance.

Undeveloped land and restricted access to the INL Site provide and protect important habitats for plants and animals. Large numbers of migratory birds of prey and mammals are funneled onto the INL Site because of its location at the mouth of several mountain valleys. The INL Site was designated as a National Environmental Research Park in 1975 (Bowman et al. 1984), and the Sagebrush-Steppe Ecosystem Reserve was created in 1999, comprising 29,947 ha (74,000 acres) of unique habitat in the northwestern portion of the INL Site. Nearly all avian, reptile, and mammalian species found across the INL Site also can be found at RWMC and are supported by various vegetation communities. Larger mammals (e.g., coyotes and antelope) are occasionally seen on facility grounds. No ecologically sensitive areas (i.e., areas of critical habitat) have been identified within RWMC.

All four major types of INL Site cultural resources (i.e., archaeological sites, contemporary Native American cultural resources, historic architectural properties, and paleontological sites) have been identified in the RWMC area. Ten major archaeological survey projects identified an inventory of 13 potentially significant prehistoric sites within a 200-m (656-ft) -wide zone surrounding the fenced perimeter of RWMC and more than 80 additional archaeological resources in the surrounding area. Paleontological remains have been identified in excavations within the facility. Shoshone-Bannock tribal members are consulted about additional resources of Native American concern. In addition, as a result of architectural surveys of 55 buildings administered by DOE within the developed portion of RWMC, three buildings have been identified as potentially eligible for nomination to the National Register of Historic Places.

E-1.1.2.4 Current and Future Land Use. Land within the INL Site is administered by DOE and is classified by the U.S. Bureau of Land Management as industrial and mixed-use acreage. Approximately 98% of land on the INL Site is open and undeveloped. Large tracts of land are reserved as buffer and safety zones around the boundary of the INL Site, while portions within the central area are reserved for INL Site operations. Remaining land within the reservation core is largely undeveloped and is used for environmental research and to preserve ecological and cultural resources. Grazing and controlled hunting are permitted. The INL Site is crossed by several highways, a rail system, and a high-voltage power distribution loop. Most work takes place within the primary facility areas (Litus and Shea 2005). Future land use (and aquifer use) is expected to remain essentially the same as current use—a research facility within INL Site boundaries, with agriculture and undeveloped land surrounding the INL Site.

E-1.1.3 Summary of Section 3—Waste Area Group 7 Description and Background

Many studies supplement the Operable Unit 7-13/14 RI/BRA and are incorporated largely by reference. Section 3 contains summaries of several of these studies, which collectively provide important elements of this remedial investigation. Topics addressed include:

- Operational background elements (e.g., analyses of collocated facilities, historical operations, buried waste retrievals, beryllium reflector block grouting, and soil-cover maintenance and repair)

- Descriptions of operable units in Waste Area Group 7 and various investigations and subsequent remedial decisions that were developed

- Source-term assessment to characterize buried waste, based on shipping records, process knowledge, and ancillary analyses

- Contaminant screening for both human health and ecological risk assessments

- Site-characterization activities (e.g., geophysical investigations, probing, actinide mobility studies, analysis of waste and soil retrieved from Pit 9, and focused monitoring of buried beryllium blocks)

- Criticality analysis for buried waste.

E-1.1.4 Summary of Section 4—Nature and Extent of Contamination

Section 4 evaluates the nature and extent of contamination for all environmental media associated with the SDA. Tens of thousands of samples have been collected near RWMC over the past three decades, and more than 100,000 analyses have been performed. The purpose of this section is to assess monitoring data to identify distributions of contaminants of potential concern associated with the SDA. Monitoring at RWMC has been conducted over time under a variety of programs and with differing objectives. Though locations for monitoring capabilities (e.g., aquifer monitoring wells, vadose zone lysimeters, and waste zone probes) were chosen based on individual program objectives, the common goal of all programs in choosing locations was to maximize the likelihood of detecting contamination. In other words, the monitoring network at RWMC has grown over time and provides data that are not statistically representative of environmental media. Despite the bias toward detection, detections are generally sparse and sporadic, typically near detection levels, and with only a few trends limited to only a few specific locations in the shallow vadose zone. Migration is very limited, with no imminent threat to the aquifer except for carbon tetrachloride, a volatile organic compound (VOC) associated with Rocky Flats Plant weapons production waste.

To assess the nature and extent of contamination, analytical data associated with contaminants of potential concern at RWMC were compiled and evaluated, encompassing analytical data from 1971 to 2004 and including results obtained by DOE, U.S. Geological Survey (USGS), and various INL Site contractors. Detected concentrations are interpreted by assessing them against comparison values. For concentrations in solid media (i.e., soil, core material, and solids filtered from samples), risk-based concentrations (RBCs) for soil are used. For water (i.e., soil-moisture, perched water, and aquifer samples), maximum contaminant levels (MCLs) established by EPA are used. The RBCs and MCLs provide a scale for interpreting significance of detected concentrations. In addition to soil RBCs and groundwater MCLs, background concentrations for soil and water provide information useful for evaluating constituents that occur naturally in the environment (e.g., nitrate and uranium isotopes) and for estimating detection frequencies.

Data for assessing the nature and extent of contamination for each contaminant of potential concern are organized as follows:

- **Waste zone—**Data sources for the waste zone are historical shipment and disposal records (e.g., constituent inventories, physical characteristics of the waste, and waste packaging) and a limited probe network equipped with vapor ports, lysimeters, and tensiometers in several focus areas.

- **Surface—**Samples of surface soil (typically the top 15 cm [6 in.]), vegetation, and run-off water collected outside of the buried waste, but within the interval of shallow surficial sediments (i.e., the region down to the first basalt interface), provide data for the surface interval.

- **Vadose zone—**Vadose zone samples have been collected from lysimeters and perched water wells up to four times a year since 1997. (The USGS has regularly collected perched water samples from Well USGS-92 since 1972.) Because of small sample volumes, analysis is conducted in accordance with a predetermined analyte priority. Soil-vapor samples also are collected routinely and analyzed primarily for VOCs.

- **Cores—**Cores are obtained when wells are drilled, and samples of interbed sediments are collected and analyzed for contaminant concentrations and physical characteristics.

- **Aquifer—**Samples have been collected from the aquifer by ICP and USGS programs since 1972. In 2004, monitoring frequency was reduced from quarterly to semiannually. Typically, a suite of radionuclides and chemicals are comprehensively analyzed.

Monitoring data indicate that some contaminants of potential concern occur in low concentrations in the vadose zone and aquifer and are likely to be attributable to waste buried in the SDA. Volatile organic compounds, particularly carbon tetrachloride, are the only widespread contaminants in the environment. The following subsections summarize the nature and extent of contamination for these intervals.

E-1.1.4.1 Waste Zone Data. Focus areas for monitoring within the waste zone were carefully selected to maximize the probability of detecting high concentrations of targeted analytes. More than 300 probes have been installed in the SDA since 1998. Most probing was directed at areas containing waste from the Rocky Flats Plant, though some of the probes targeted waste generated by INL Site operations. Sites for probing were based primarily on historical disposal records. Concentrations detected in these focus areas are high for analytes targeted by the probing, corroborating disposal records, and demonstrating success in choosing locations for waste zone monitoring. The most frequently detected analytes, in order of detection frequency, are VOCs, plutonium isotopes, Am-241, and uranium isotopes.

In general, constituent profiles and ratios confirm successful penetration of waste types targeted in each focus area. For example, organic compounds and radionuclides detected in the Depleted Uranium Focus Area in 2004 were compared to waste-disposal inventories in this area, and good correlation was noted. Analytical indicators (e.g., plutonium isotope activity ratios and ratios of various organic compounds) indicate that areas expected to contain waste from the Rocky Flats Plant are primarily composed of weapons-manufacturing waste.

E-1.1.4.2 Surface. Hundreds of surface soil, vegetation, and run-off water samples have been collected and analyzed for numerous analytes over the past 10 years. Most constituents at RWMC are measured at concentrations near surficial soil background levels, and none have exceeded soil RBCs. Of the contaminants of potential concern, Pu-239/240 and Am-241 are the most frequently detected in surface soil samples (i.e., within the top 15 cm [6 in.]) inside and outside the SDA, at detection rates of about 22 and 21%, respectively. The high number of Pu-239/240 detections compared to Pu-238 suggests the plutonium is either from weapons-manufacturing waste in the SDA or from fallout. Americium-241 and Pu-239/240 concentrations generally are low; however, presence of these contaminants at detectable levels in the surface environment around the RWMC area emphasizes the importance of following radiological control procedures to minimize cross contamination when drilling and installing new monitoring wells and collecting samples. Surface contamination outside the SDA also substantiates the likely origin of Pu-239/240 detected during aquifer well drilling, installation, and sampling in the early 1970s. Detections in samples of vegetation and run-off water were few, and their contributions to the assessment of Pu-239 concentrations were insignificant.

E-1.1.4.3 Vadose Zone Soil Moisture and Perched Water. Various radionuclides and chemicals are detected in the vadose zone. Except for VOCs, most constituents are detected only sporadically and have no associated temporal or spatial trends. A few constituents are consistently detected in the vadose zone (see Figure E-3), exhibit concentration trends, and show evidence of migration. Vadose zone constituents that have been identified as contaminants of potential concern, in order of their detection frequency from highest to lowest, are VOCs, uranium isotopes, nitrate, Tc-99, and C-14. The following subsections summarize these constituents.

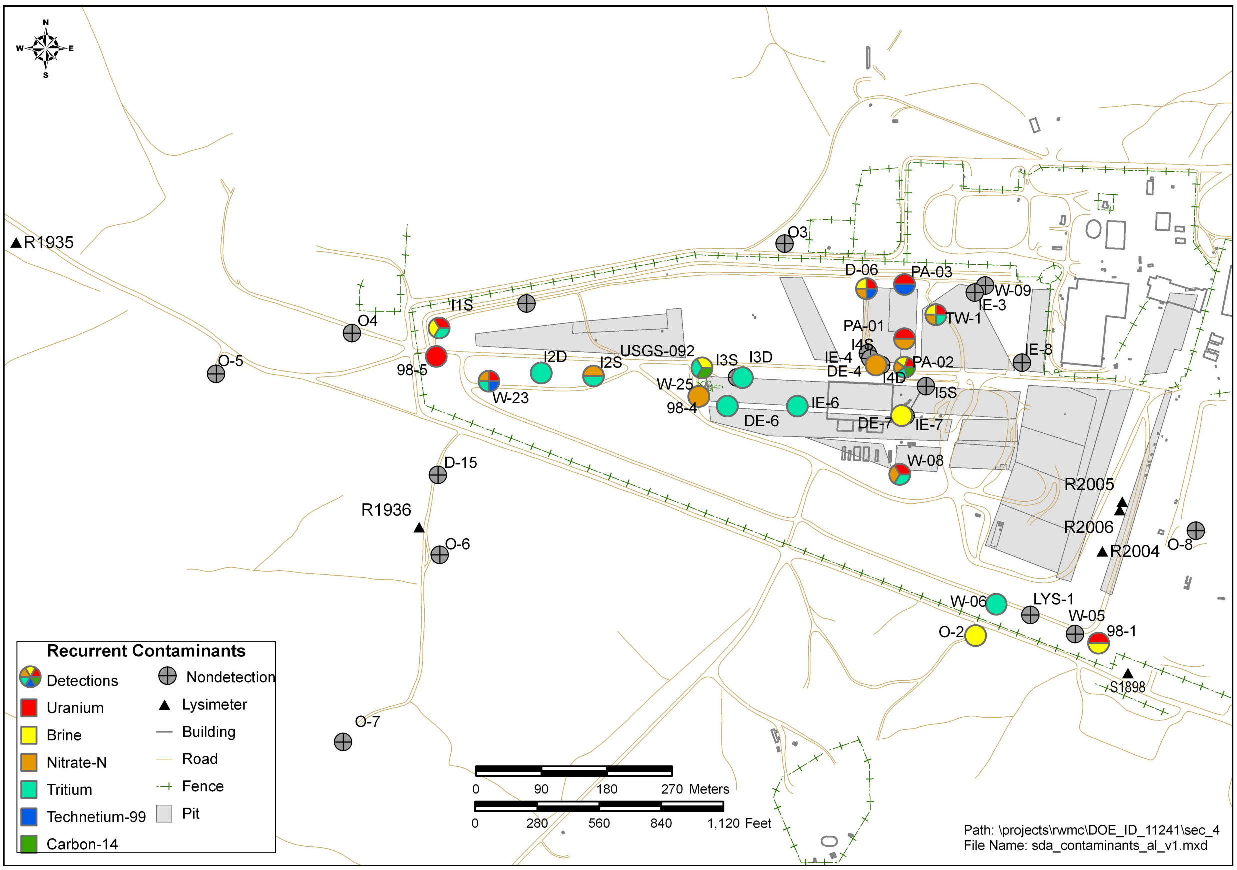

Figure E-3. Recurring constituents in vadose zone lysimeters.

E-1.1.4.3.1 Volatile Organic Compounds—Carbon tetrachloride, tetrachloroethylene, and trichloroethylene are consistently detected in perched water and lysimeter samples. Each has been detected above MCLs in perched water samples and in shallow, intermediate, and deep lysimeter samples. Methylene chloride is detected less frequently and at lower concentrations. Methylene chloride has been detected above the MCL in shallow lysimeter and perched water samples, but has not been detected in any intermediate or deep lysimeter samples.

E-1.1.4.3.2 Uranium Isotopes—Uranium concentrations in all but one location in the vadose zone and aquifer are consistent with naturally occurring uranium. The one exception, TW1:DL04 in Pit 5 near Pad A, exhibits concentrations and isotopic ratios that clearly indicate uranium at this location is anthropogenic and slightly enriched with U-235. This interpretation is further supported by thermal ionization mass spectrometry analysis of a TW1 sample in 1999 (Roback et al. 2000). Concentrations exceeding local background levels are most prevalent in shallow and intermediate depths of the vadose zone near three specific areas in the SDA—around Pad A and Pit 5, the western end of the SDA, and the Acid Pit. Though elevated levels of uranium at these locations are within the range of naturally occurring uranium, other contaminants also are detected in these same locations, indicating some migration may be influencing sample results.

E-1.1.4.3.3 Nitrate—Nitrate concentrations at many monitoring locations are above the local soil-moisture upper background range; however, because of background variability, only five monitoring locations have concentrations high enough above the upper background range to confidently declare that nitrate is likely from anthropogenic sources (i.e., Wells D15, I2S, W08, W25, and 98-4). The high nitrate concentrations are predominantly found in shallow- and intermediate-depth intervals. Concentration trends are evident at monitoring Lysimeters I2S, PA02, and W25, which are located by Pad A and in the western part of the SDA at depths around 30.5, 2.7, and 4.9 m (100, 9, and 16 ft), respectively (see Figure E-3). Nitrate measured at Lysimeter PA02 by Pad A appears to be migrating downward because concentrations at Well I4S, about 30.5 m (100 ft) below Pad A, have started increasing.

E-1.1.4.3.4 Technetium-99—Technetium-99 is consistently detected at depths of 27 m (88 ft) in two locations: Well D06 by Pad A and Well W23 at the western end of the SDA (see Figure E-3). The concentration associated with Well D06 is increasing. Historically, Tc-99 has not been a priority analyte for vadose zone monitoring; therefore, data are sparse.

E-1.1.4.3.5 Carbon-14—Carbon-14 concentrations around beryllium blocks are substantially higher than C-14 concentrations near activated steel or other low-level waste disposals. Carbon-14 is detected intermittently in soil-moisture samples (see Figure E-3), but is readily detected in vapor samples collected near beryllium blocks and activated stainless steel. Carbon-14 also is detected in vapor samples collected from Organic Contamination in the Vadose Zone vapor ports at depths from 11 to 51 m (35 to 166 ft). Collecting samples with suction lysimeters (vacuum) may volatilize the C-14 and produce nondetections or biased-low concentrations. This may explain why C-14 is detected only intermittently in soil-moisture samples.

E-1.1.4.4 Cores. Few radionuclides are detected in core samples. Most are detected only sporadically and have no associated temporal or spatial trends; however, some radionuclides are consistently detected in RWMC core samples. In order of detection frequency from highest to lowest, these radionuclides are Tc-99, Am-241, Pu-239/240, Sr-90, and Pu-238.

Sample concentrations are generally very low and below soil RBCs used for comparison. Americium-241, Pu-238, and Pu-239/240 were detected primarily in the 0 to 10.7-m (0 to 35-ft) and 11-to 42.7-m (35 to 140-ft) depth intervals, with very few detections deeper than 43 m (140 ft) (i.e., for Tc-99, 10 detections out of 28 analyses; for Am-241, four detections out of 161 analyses; for Pu-239/240, five detections out of 175 analyses; for Sr-90, nine detections out of 158 analyses; for Pu-238, five detections out of 175 analyses). Concentrations of these actinides ranged from 0.002 to 9.6 pCi/g, with a mean concentration around 0.25 pCi/g. Most Am-241 detections were not corroborated with detections of other actinides (e.g., Pu-238 and Pu-239/240), except at monitoring locations in Pit 5, where Pu-238 and Pu-239/240 also were detected. Most valid plutonium and americium detections (i.e., those not taken between 1971 and 1974) are located in the Pit 5 area and the western part of the SDA (see Figure E-4). All plutonium detections in the 10.7 to 42.7-m (35 to 140-ft) depth interval occurred between 30 and 34 m (98 and 111 ft), which is the location of the B-C interbed. This substantiates the conclusion by Batcheller and Redden (2004) that plutonium (and probably other contaminants) is effectively immobilized in sedimentary interbeds.

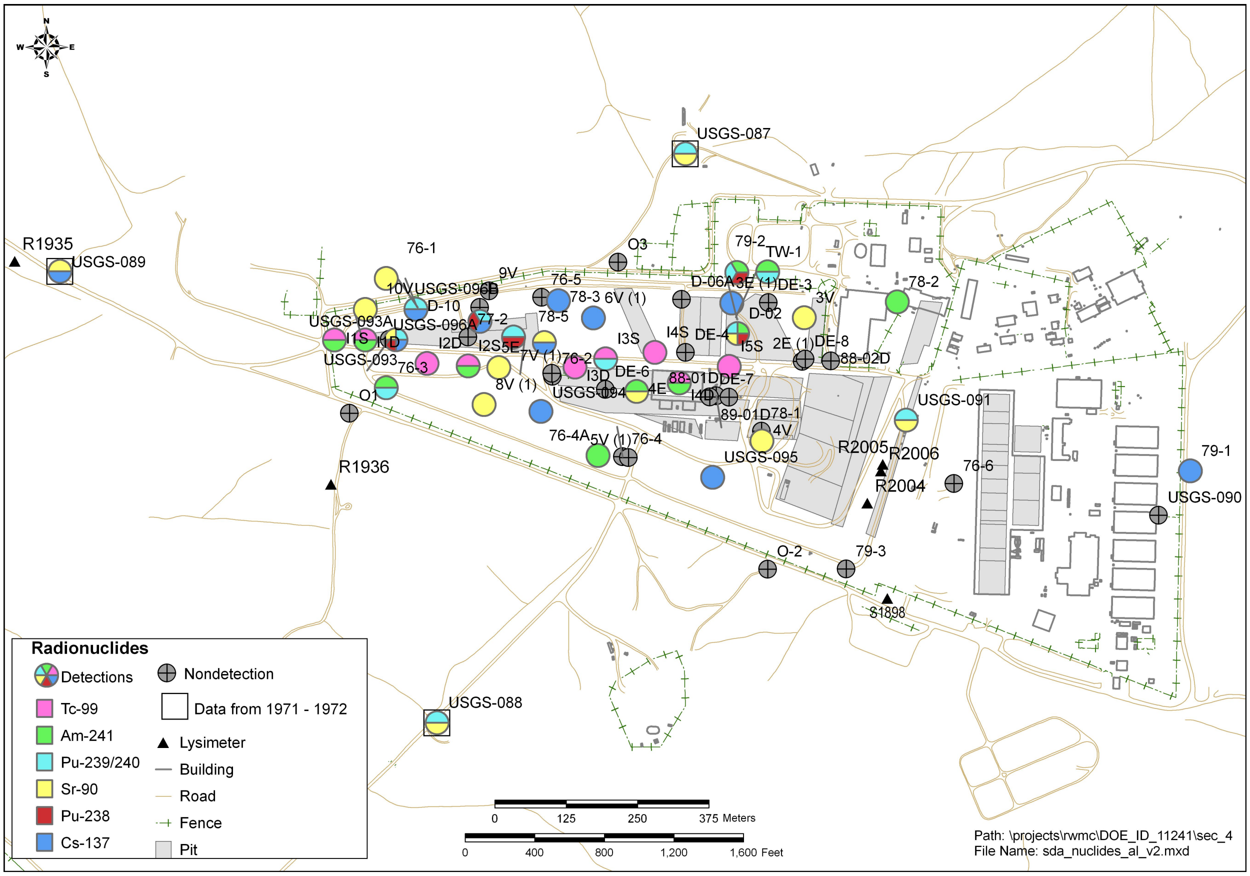

Figure E-4. Radionuclides detected in core samples between 1971 and 2003.

Detections of Tc-99 in the I-series wells in 1999 were not corroborated by detections in the 2003 core sampling campaign. Some evidence supports the conclusion that Tc-99 is present, while some evidence is to the contrary. However, lysimeter data imply Tc-99 transport may be occurring.

E-1.1.4.5 Vadose Zone Soil Gas. Volatile organic compounds are consistently detected in soil-gas samples from land surface to the aquifer and as far as 1 km (3,281 ft) beyond the SDA. Thousands of gas samples have been collected from more than 100 permanent soil-gas sampling ports inside and outside the SDA. Compounds are analyzed with an instrument that measures concentrations of the following five compounds, in order of highest to lowest average concentration: carbon tetrachloride, chloroform, trichloroethylene, 1,1,1-trichloroethane, and tetrachloroethylene.

Except for chloroform, these are primary volatile organic constituents in Series 743 sludge received from Rocky Flats Plant. Very little chloroform was buried in the SDA; but because it is a degradation product of carbon tetrachloride, it is ubiquitous in soil gas. Soil-gas samples are not analyzed for methylene chloride and 1,4-dioxane.

Concentrations of VOCs in soil gas have been reduced by the Operable Unit 7-08 vapor vacuum extraction with treatment system that has operated since 1996. Concentrations near active source areas have been impacted less by the remediation system.

E-1.1.4.6 Aquifer. Very few contaminants of potential concern are regularly detected at levels greater than background concentrations in the aquifer near RWMC. Those frequently detected contaminants of potential concern, in order of detection frequency from highest to lowest, are carbon tetrachloride, trichloroethylene, uranium isotopes, and Cs-137. Other constituents that are not contaminants of potential concern are regularly detected in concentrations greater than aquifer background values. Those other constituents, in order of detection frequency from highest to lowest, are tritium, sulfate, chloride, chromium, and toluene. Figure E-5 illustrates constituents detected in the aquifer near RWMC.

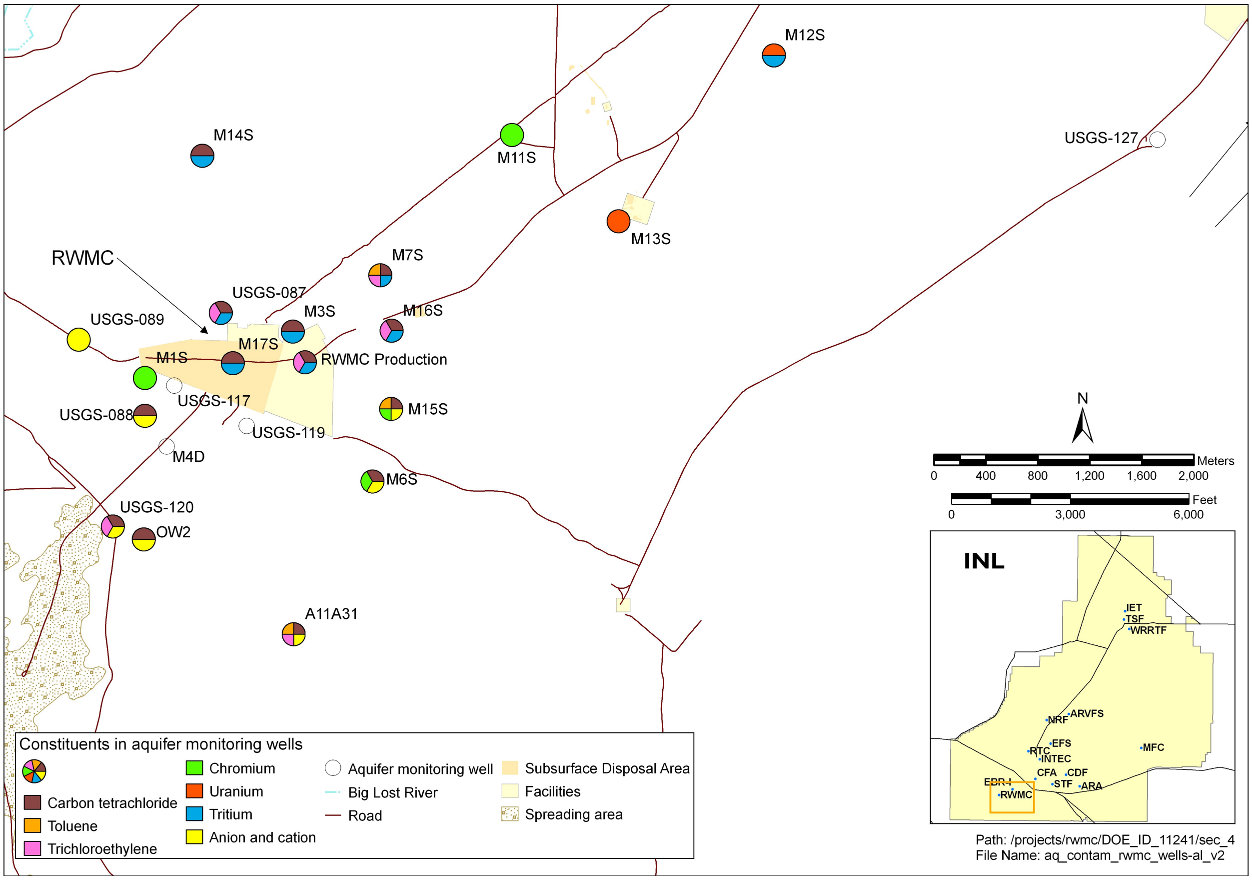

Figure E-5. Constituents in aquifer monitoring wells.

Some constituents are intermittently detected in the aquifer near RWMC. Those intermittently detected constituents, in order of detection frequency from highest to lowest, are bromide (not a contaminant of potential concern), magnesium (not a contaminant of potential concern), C-14, nitrate, Pu-238, Am-241, Pu-239/240, methylene chloride, and tetrachloroethylene. Detection frequencies are low. For example, Pu-238 plus Pu-239/240 are detected at a rate of 1.0%, which is slightly lower than the detection rate of blank samples (1.2%) and is also the number of times a result is expected to occur outside the 99.7% confidence interval (i.e., a false positive detection).

The only contaminant of potential concern that exceeds its MCL is carbon tetrachloride, which is consistently detected in numerous aquifer monitoring wells at concentrations near and occasionally greater than the MCL of 5 µg/L. Toluene and trichloroethylene also are detected frequently at certain locations in the aquifer beneath the SDA, but concentrations are significantly less than MCLs, and concentration trends are not evident. Low levels of tritium, chromium, and nitrate, as well as a few anions and cations, are detected consistently above background levels in the aquifer beneath RWMC; however, the source of these constituents is uncertain. Possible sources could be transport from the SDA, contributions from upgradient facilities, or corroding well construction material.

Analytical evidence shows intermittently detected contaminants (i.e., C-14, nitrate, Pu-238, Am-241, Pu-239/240, methylene chloride, and tetrachloroethylene) are not widespread in the aquifer near RWMC, and they are not migrating at measurable concentrations. Nitrate concentrations in monitoring Well M6S are higher than all other RWMC aquifer monitoring wells; however, the long-term trend appears to have leveled off at concentrations near the upper background range.

Segregation in the aquifer is observed around RWMC. Tritium is detected only in monitoring wells north of RWMC; high anions and cations (i.e., chlorine, bromine, sulfate, magnesium, and nitrate) are found in wells south of RWMC. Trichloroethylene and toluene are located to the east and south, and high chromium concentrations are isolated to the low-permeability zone beneath the southern RWMC boundary. Excluding VOCs, upgradient concentrations are attributable to other facilities (see Section 2.3.4).

E-1.1.4.6.1 Carbon Tetrachloride—Low levels of carbon tetrachloride are consistently detected in aquifer monitoring wells in and around RWMC (see Figure E-5). The maximum concentration was 8 µg/L measured in Well M7S. Concentration trends of carbon tetrachloride in many RWMC aquifer monitoring wells appear to be stabilizing and perhaps declining slightly; however, concentrations in Wells M7S, M16S, RWMC Production Well, and A11A31 continue to fluctuate slightly above and below the MCL of 5 µg/L. No wells exhibited an obvious increasing trend over the past few years, but Well USGS-120 has shown a decreasing trend.

E-1.1.4.6.2 Trichloroethylene—Trichloroethylene is routinely detected at low levels in aquifer monitoring wells in and around RWMC (see Figure E-5). The maximum concentration was 3.9 µg/L measured in Well USGS-90 in 1988. Since 2000, the highest concentrations measured were 3.3, 3.2, and 3.0 µg/L in Wells RWMC Production, A11A31, and M7S, respectively. Concentration trends of trichloroethylene in most RWMC aquifer monitoring wells are stable. Trichloroethylene has not been detected in the aquifer above the MCL of 5 µg/L.

E-1.1.4.6.3 Uranium Isotopes—Concentrations of uranium detected in aquifer monitoring wells are consistent with natural background values and have never approached or exceeded the MCL for total uranium. The number of detections of U-233/234 and U-238 exceeding the upper background comparison concentrations is consistent with expected rates (i.e., less than or equal to 1%). The detection rate for U-235/236, which is slightly higher than those for U-233/234 and U-238, is attributed to (1) relatively high measurement uncertainties associated with low-level U-235/236 analyses and (2) a low upper background comparison concentration at RWMC (ranges at other aquifer monitoring locations around the INL are typically a factor of two higher than at RWMC).

E-1.1.4.6.4 Cesium-137—The detection rate of Cs-137 for aquifer samples is also very low (i.e., 1.5%), but slightly higher than the expected rate. Many detections contributing to the rate occurred in the early 1970s and are artifacts of well drilling and sampling methods employed at the time. The MCL was exceeded in one aquifer sample collected in 1995; however, Cs-137 has not been detected at that sampling location in subsequent sampling events.

E-1.1.4.7 Ecological Contaminants of Potential Concern. Ecological risk assessments conducted at the INL Site are based on evaluation and interpretation of the nature and extent of contamination conducted for human health (Van Horn, Hampton, and Morris 1995). Samples have not been collected and analyzed to specifically address RWMC ecological receptors, and sampling data collected as part of the human health assessment were not analyzed in terms of nature and extent for